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ÉKON-VT OXYGEN GAS ANALYZER AND OPERATING EXPERIENCE

E. I. Chernov,[1, 3] M. E. Chernov,[1] V. I. Samsonov,[2] B. E. Gvozdev,[2] and Sh. N. Kyazymov[2]

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The high-temperature (to 1400°C), stationary, non-sampling gas analyzer ÉKON-VT (Ékon JSC, Obninsk) has been developed, certified, and put into operation. This analyzer is designed to measure the oxygen content during various technological processes associated with burning fossil fuels, for example, in industrial furnaces for firing ceramics and glassmaking, incinerator furnaces, and other applications. This apparatus makes it possible to optimize the fuel combustion regime, stabilize the parameters of the technological regime for firing ceramics, and increase the effectiveness of furnace control and the quality of the ceramics produced.

Key words: oxygen gas analyzer, sensor, industrial furnaces, optimal combustion regime, residual oxygen content, firing ceramic.

One of the most promising directions in efforts to increase fuel utilization efficiency, decreasing the consumption of fossil fuels, decreasing environmentally harmful emissions, and increasing the service life of industrial furnaces is establishing the optimal ratio between the fuel entering the combustion zone and air (oxygen). It is well known that to realize an ideal combustion regime the amount of inflowing air must be necessary and sufficient for burning the fuel completely, i.e., the coefficient of excess air must be 1 ($K_{exc} = 1$). Thus, for example, about 9.52 m^3 of air is required to burn 1 m^3 of natural gas.

However, under real conditions K_{exc} can vary over wide limits and be both greater and less than 1 in different furnace operation regimes. If the oxygen content in the combustion zone is too high, then fuel losses to burning the excess air are substantial, i.e., heat is lost and the specific heat consumption increases. It has been established that every volume percent of excess oxygen (specific heat at 500 – 1500°C is 14,168 – 15,295 kJ/($m^3 \cdot$ K)) decreases the efficiency of a heating unit by more than 1%. In addition, if too much air is used for combustion, the pressure and velocity of the waste gases increase, which causes the equipment to wear out prematurely and can also result in an elevated content of nitrogen oxides in the waste gases.

On the other hand, if the amount of air (oxygen) entering the combustion zone is too low, then combustion is incomplete and therefore the fuel consumption is too high and the oxidation potential of the technological medium of the furnaces changes, which lowers the quality of the product. In addition, the surrounding medium is polluted by oxides of sulfur and carbon as well as other environmentally harmful compounds.

Thus, it is completely obvious that the oxygen content in the gas phase of industrial furnaces must be monitored, and this monitoring must be accurate, timely, and continuous.

In world and domestic practice today, an oxygen gas analyzer using solid electrolytes is the most effective apparatus for measuring the oxygen content in waste gases of heating units.

ÉKON, JSC (Kaluga Oblast', Obninsk) possesses high scientific–technical resources and has been working for more than 12 years to develop and build an oxygen gas analyzer based on solid electrons for power-engineering. As a result oxygen gas analyzers for boiler units have been developed, certified, and are now in serial production. These analyzers have been installed in more than 500 plants in the domestic energy industry. The ÉKON gas analyzers possess an entire host of technical features which make it possible to operate the units reliably for long times at high temperatures and in corrosive gas media: high measurement accuracy and fast operation, high reliability, capability of working with any recording and controlling devices and automated control systems. The extended 1-yr intercalibration period and a 5-yr average service life as well as no need for reference gases all advantageously distinguish the ÉKON gas analyzer from its competitor's analogs.

In 2007 – 2009 the ÉKON JSC developed and certified the first Russian high-temperature stationary non-sampling gas analyzer ÉKON-VT for monitoring oxygen at tempera-

[1] ÉKON, JSC, Obninsk, Kaluga Oblast', Russia.
[2] Obninsk Scientific and Industrial Enterprise "Tekhnologiya", Obninsk, Russia.
[3] E-mail: econ@obninsk.ru.

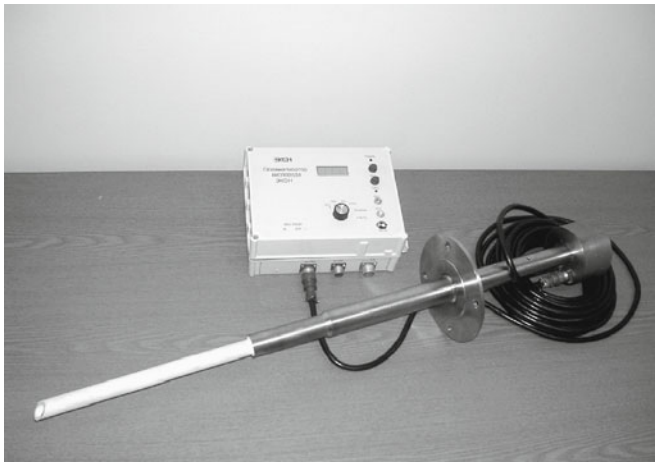

Fig. 1. ÉKON-VT gas analyzer.

tures from 700 to 1400°C in industrial furnaces for firing ceramics, glassmaking furnaces, incinerators, and other units (certificate RU.C.31.000A No. 35763, August 20, 2009, No. 13520–03 in the government registry of means of measurement).

The gas analyzer consists of an immersion sensor and an electronic block (Fig. 1). The case of the sensor is a compound structure. It is made of heat-resistant stainless steel and oxide ceramic. The case encloses a solid-electrolytic sensitive element, a thermocouple, a ceramic filter for removing aerosols from the gas being analyzed, and a system for feeding a reference gas to the electrode.

The sensor is placed in a special opening in the furnace wall horizontally or vertically in a manner so that the "ceramic" part of the case emerges into the high-temperature (working) zone.

The electronic block, connected with the sensor by means of a heat-resistant cable up to 300 m long, shows the instantaneous value of the oxygen concentration and temperature of the sensitive element and it also forms a unified signal 0 – 5 and 4 – 20 mA, proportional to the oxygen content in the gas being monitored. In addition, the electronic block can be equipped with an RS 485 MODBUS.RTU coupling channel for connecting external devices (PCs).

Thus, the new high-temperature oxygen gas analyzer ÉKON-VT can be used in a system that automatically regulates the combustion process in technological furnaces.

In 2008 an ÉKON-VT high-temperature oxygen gas analyzer was installed in a gas-burning continuous furnace for firing ceramics D-180-60VS in shop No. 92 at the Federal State Unified Enterprise Obninsk Scientific and Industrial Enterprise "Tekhnologiya" (Obninsk) to perform production tests and undergo experimental operation (Fig. 2).

The sensor of the gas analyzer was placed horizontally in an existing service opening in the furnace wall and the electronic block was placed ~5 m from the sensor. The temperature of the working zone of the furnace was 1440 – 1540°C. The temperature of the gas being monitored in the zone of

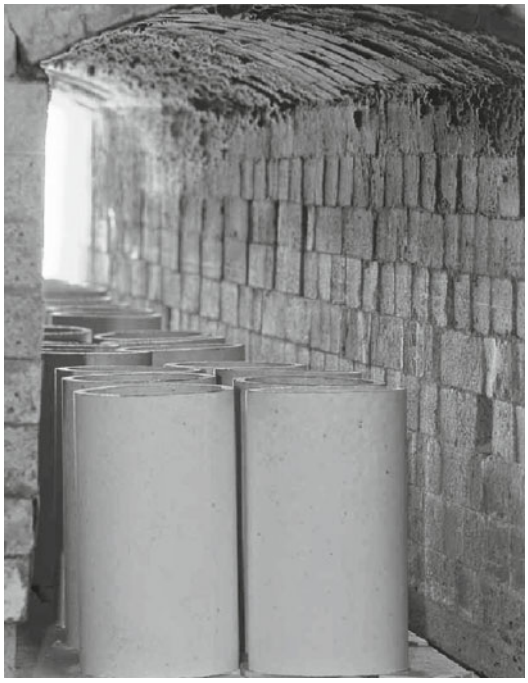

Fig. 2. Firing of ceramic articles in a D-180-60VS continuous gas furnace.

the sensitive element of the sensor was in the range 700 – 760°C. The oxygen concentration and the temperature in the working zone of the furnace were changed by changing the flow rate of the gas and air which are fed into the combustion zone.

Before the ÉKON-VT gas analyzer was put into operation the prescribed temperature regime of the furnace was set in accordance with the schedule of the technological process on the basis of the indications of the sensors measuring the pressure in the gas and air lines and was supported by the experience gained by the service staff. Often, for constant indications of the parameters of the technological process of firing a ceramic it was impossible to repeat one and the same process because it was impossible to attain a prescribed temperature in the furnace, even though the flow rate of the feed gas increased.

With the oxygen gas analyzer placed directly in the combustion zone it was determined that for constant values of the pressure of the gas and air entering the furnace on different days the content of the residual oxygen in the furnace varied from 0.1 to 8 vol.%. The temperature changed in the process.

Using the indications of an atmospheric pressure barometer it was found that the change in the content of residual oxygen in the furnace is due to the magnitude and rate of change of the atmospheric pressure. For example, it was found that as the atmospheric pressure drops the gas analyzer records the decrease of the oxygen content in the gas medium of the furnace, immediately after which the temperature of the technological process decreases. This is due to the change of the oxygen partial pressure in the atmosphere with

a change of the atmospheric pressure. For example, a change of the pressure by 30 mm Hg (from 760 to 730 mm Hg) decreases the oxygen volume content from 20.9 to 20.1%.

In addition, the humidity of the atmospheric air fed into furnace affects the residual oxygen content in the continuous furnace, since it is directly related with the content of oxygen in it. For example, increasing the relative humidity of the air from 30 to 100% at 20°C decreases the volume content of oxygen from 20.9 to 20.5%.

Thus, the operating regime of a continuous atmospheric furnace is directly related with the parameters of the atmospheric air — pressure and humidity. A change of these parameters requires continuous and timely monitoring of the oxygen content during the combustion process.

The regularities which had been established have made it possible to develop and use an algorithm for manual control of the furnace. This algorithm is based on the indications of the ÉKON-VT gas analyzer. Timely information on the oxygen content enables the operator to increase or decrease the amount of air fed into the combustion zone and thereby to act on the temperature regime of the technological process on time in order to optimize it.

In the course of the tests the fuel – air ratio was briefly changed within the limits of the allowed by the technological process. In the process the operator periodically recorded the indications of the instrument and manually adjusted the flow of air and gas, which are fed into the combustion zone, on the basis of the oxygen content and the temperature. During the tests the ÉKON-VT gas analyzer was used to measure continually the oxygen content in the working zone of the furnace in the process of regular technological regime for firing ceramic articles; the indications of the sensor fell into the interval from 0.1 to 7 vol. %. An increase of the air flow rate increased the indications of the sensor and a decrease of the air flow rate decreased the measured oxygen content in the working zone, in complete agreement with the stoichiometry of the process of combustion of fossil fuels.

The results of the trial operation of the gas analyzer also showed that the high-pressure fans on the D-180-60-VS furnace must be upgraded in order to be able to increase the amount of air fed into the combustion zone. This work was completed, and as a result it was possible to solve the problem of maintaining the optimal temperature regime of the furnace during firing of a ceramic.

Continual timely monitoring of oxygen in the combustion zone enabled the operator to maintain the optimal combustion regime with residual oxygen content 1 – 2 vol.% and temperature 1500 – 1540°C. The permitted main error did not exceed the established value ± 3.0%.

The positive results from testing the instrument and the development of a principle for maintaining reliably a prescribed temperature regime during the operation of the facility have made it possible to develop an automated system, based on the ÉKON-VT gas analyzer, for regulating (controlling) the temperature in high-temperature gas furnaces. This will make it possible to optimize the fuel – air ratio, which in turn will not only improve production quality, reduce the number of rejects, and save fuel but also to lower the environmentally harmful emissions into the atmosphere.

CONCLUSIONS

The ÉKON-VT gas analyzer has made it possible to optimize the fuel combustion regime in the D-180-60-VS ceramic firing furnace in the No. 92 shop at the Federal State Unified Enterprise Obninsk Scientific and Production Enterprise “Tekhnologiya” (Obninsk), to stabilize the parameters of the technological regime for firing ceramics, to increase the effectiveness of furnace control, and to improve technological discipline. In addition, monitoring the oxygen content revealed that an additional fan must be installed and made it possible to upgrade the system feeding air into the combustion zone of the furnace as well as to plan the implementation of the automatic regulation of the process of controlling the feeding of the fuel – air mixture into the burners of the D-180-60 VS.

The positive results obtained from the trial operation of the ÉKON-VT gas analyzer make it possible to recommend using this apparatus as a regular means for monitoring oxygen in the combustion zone — the most important technological parameter of the process of fuel combustion in furnaces for firing ceramics as well as in glassmaking and other furnaces.